

SPECIFICATION

IBM Docket No. SVL9-2003-0131-US1

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN that we, Allen K. Hawley, of San Jose, California and citizen of the United States, and Pavan K. Immaneni of San Jose, California and citizen of India, have invented new and useful improvements in

LANGUAGE INDEPENDENT CODE ASSIST USER PREFERENCES CONFIGURATION METHOD, SYSTEM, ARTICLE OF MANUFACTURE, AND COMPUTER PROGRAM PRODUCT

of which the following is a specification:

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2
3 **LANGUAGE INDEPENDENT CODE ASSIST USER PREFERENCES CONFIGURATION**
4 **METHOD, SYSTEM, ARTICLE OF MANUFACTURE, AND COMPUTER PROGRAM**
5 **PRODUCT**
6
7
8
9

10 **CROSS-REFERENCE TO RELATED APPLICATIONS**
11

12 Application Serial Number _____, filed concurrently herewith on December 9, 2003
13 for USER CONFIGURABLE LANGUAGE INDEPENDENT CODE ASSIST ENGINE METHOD,
14 SYSTEM, ARTICLE OF MANUFACTURE, AND COMPUTER PROGRAM PRODUCT (IBM
15 Docket STL9-2003-0037-US1), currently co-pending, and assigned to the same assignee as the
16 present invention; and

17 Application Serial Number _____, filed concurrently herewith on December 9, 2003
18 for USER CONFIGURABLE LANGUAGE INDEPENDENT CODE ASSIST METHOD,
19 SYSTEM, ARTICLE OF MANUFACTURE, AND COMPUTER PROGRAM PRODUCT (IBM
20 Docket STL9-2003-0130-US1), currently co-pending, and assigned to the same assignee as the
21 present invention.

22 The foregoing co-pending applications are incorporated herein by reference.
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BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates in general to computer programs, and more particularly to providing assistance to a programmer creating computer program code.

2. Description of the Related Art

[0002] A code assist or content assist is a function which aids a programmer in writing a computer program statement by suggesting proposals or candidates for insertion into the computer program statement. The programmer may select one of the proposals or candidates in order to supplement, modify, complete, or replace a computer program statement being edited.

[0003] Conventional code assist functions are exemplified by the Eclipse Project code assist function as described in the Eclipse Project Java Development User Guide, (c) Copyright IBM Corp. 2000, 2001, pages 9-12, <http://www.eclipse.org/eclipse/index.html>. The Eclipse Project code assist function provides a programmer with suggested assistance in writing Java code. The programmer may activate the Eclipse Project code assist function from a Java code editor on a line of Java computer program code which causes a scrollable list of available Java code completions to be displayed. The programmer may then select one of the proposed Java code completion candidates from the scrollable list to be inserted to complete the line of Java computer program code.

[0004] The programmer may also configure the behavior of the Eclipse Project code assist by selecting or specifying various preferences in a Code Assist tab within a Java Editor preference page. Color preferences allow the programmer to specify the colors used for the code assist window and the colors used when showing method parameters. An alphabetical sort preference, if enabled, causes proposals to be sorted in alphabetical order. A visibility preference limits displayed proposals

in the list by Java visibility rules to only those proposals visible in a current invocation context. An argument name preference, if enabled, causes a selection of a Java method proposal to additionally insert the Java method's argument names as specified in the Java method's declaration. A qualified versus import name preference allows the programmer to select whether the code assist function inserts fully qualified names for type proposals or inserts non-qualified names for type proposals in conjunction with an addition of the corresponding import declaration. A preference for automatic insertion of a single proposal when the proposal list only contains the single proposal may be specified. The user may also specify preferences as to the code assist function's activation behavior. An auto activation preference may specify that code assist is invoked automatically in response to specified character triggers after a specified time delay.

[0005] Even with these capabilities and user-specified preferences, conventional code assist functions still fail to provide adequate assistance for a programming language which allows a variation in valid syntax for a particular command or verb, a variation in keyword representations for a particular keyword, variations in valid argument types for a particular command or verb, or variations in style such as character case. In view of these possible variations, a user may prefer only one of the variations, or the user may prefer to be reminded of all of the possible variations.

[0006] In particular, these conventional code assist functions fail to provide adequate assistance for variable-syntax programming languages such as COBOL or PL/I having these complexities. Complex languages such as COBOL may have numerous variations in syntax for a single statement. For example, a COBOL GOTO statement has the syntax: "GO" ["TO"] procedure-name, which gives rise to two format variations: "GO TO procedure-name" and "GO procedure-name". The COBOL MOVE statement has the following syntax:

"MOVE" [CORRESPONDING | CORR] {identifier-1 | literal-1} "TO" identifier-2

and has six format variations:

"MOVE CORRESPONDING identifier-1 TO identifier-2"

"MOVE CORRESPONDING literal-1 TO identifier-2"

"MOVE CORR identifier-1 TO identifier-2"

1 "MOVE CORR literal-1 TO identifier-2"

2 "MOVE identifier-1 TO identifier-2"

3 "MOVE literal-1 TO identifier-2"

4 In a complex language such as COBOL, keywords may have alternative spellings. For example,
5 COBOL keywords may have the following alternative spellings: "CORRESPONDING" or "CORR",
6 "IDENTIFICATION" or "ID", "JUSTIFIED" or JUST, "PICTURE" or "PIC", "SYNCHRONIZED"
7 or "SYNC", and "THROUGH" or "THRU". Alternatively, keywords or reserve words may be
8 optional, such as the optional keyword "TO" in the above GOTO statement or the optional keyword
9 CORRESPONDING in the above MOVE statement. Further complexities may result from
10 keywords dictating a subsequent format of a statement, or from a format being recursive.

11

12 [0007] A programmer desiring an effective code assist function for such a complex programming
13 language needs a code assist function which supports such complexity variations, supports user-
14 specified preferences for such complexity variations, and which effectively provides suggested
15 proposals for completing programming statements having such complexity variations. However,
16 conventional code assist functions fail to provide this. Thus, there is a clearly felt need for an
17 improved code assist function for such complex language variations.

SUMMARY OF THE INVENTION

[0008] Preferred embodiments of the present invention comprise a method, system, article of manufacture, and computer program product for providing code assist.

[0009] In accordance with a preferred embodiment of the present invention, a code assist function which suggests candidates responsive to a parsing of a partial program instruction statement is configured by displaying a list of user-selectable preferences; allowing a user to select one of the user-selectable preferences; storing the selected one of the user-selectable preferences; and configuring the code assist function to display the selected one of the user-selectable preferences responsive to a parsing of a partial program instruction statement. User-selectable preferences may be selected such as a longer or shorter list of candidates; a longer or shorter representation keyword candidates; a full syntax or partial syntax representation of a candidate; and a character case representation of a candidate.

[0010] A preferred embodiment of the present invention has the advantage of providing an improved code assist function.

[0011] A preferred embodiment of the present invention has the advantage of providing an improved user interface for a code assist function.

[0012] A preferred embodiment of the present invention has the advantage of providing a user-configurable set of user preferences for configuring an operation of an improved code assist function.

[0013] A preferred embodiment of the present invention has the advantage of providing an improved code assist function supporting multiple computer programming languages.

[0014] A preferred embodiment of the present invention has the advantage of providing an improved code assist function supporting multiple syntax and format variations for a single computer programming statement.

1 **[0015]** A preferred embodiment of the present invention has the advantage of providing an
2 improved code assist function supporting multiple keyword variations for a particular keyword of a
3 computer programming statement.
4

5 **[0016]** A preferred embodiment of the present invention has the advantage of providing an
6 improved code assist function supporting optional keywords for a particular computer programming
7 language command or verb.
8

9 **[0017]** A preferred embodiment of the present invention has the advantage of providing an
10 improved code assist function supporting computer programming language commands or verbs
11 containing recursive syntax.
12

13 **[0018]** A preferred embodiment of the present invention has the advantage of providing an
14 improved code assist function providing a list of commands or verbs, key words, identifier names,
15 and literal names as proposals at a current cursor position in a computer program statement.
16

17 **[0019]** A preferred embodiment of the present invention has the advantage of providing an
18 improved code assist function providing a user-selectable choice of either a shorter list or a longer
19 list of proposals.
20

21 **[0020]** A preferred embodiment of the present invention has the advantage of providing an
22 improved code assist function providing a user-selectable preference as to a case of a proposal: upper
23 case, lower case, or mixed case.
24

25 **[0021]** A preferred embodiment of the present invention has the advantage of providing an
26 improved code assist function providing a user-selectable choice from available formats for a
27 particular command or verb.
28

29 **[0022]** A preferred embodiment of the present invention has the advantage of providing an
30 improved code assist function providing a user-selectable choice of either full or abbreviated
31 representations of a keyword.

1 **[0023]** A preferred embodiment of the present invention has the advantage of providing an
2 improved code assist function displaying a suggested candidate responsive to a determination of
3 declared variables and constants.

4
5 **[0024]** A preferred embodiment of the present invention has the advantage of providing an
6 improved code assist function displaying a suggested candidate responsive to a determination of a
7 code segment containing a partial program instruction statement.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] For a more complete understanding of the present invention and the advantages thereof, reference is now made to the Description of the Preferred Embodiment in conjunction with the attached Drawings, in which:

Figure 1 through Figure 7 are graphical user interfaces used in a preferred embodiment of the present invention;

Figure 8 is a block diagram the preferred embodiment of the present invention;

Figure 9 is a class diagram of the preferred embodiment of the present invention;

Figure 10 through Figure 12 are flowcharts of method steps preferred in carrying out the preferred embodiment of the present invention; and

Figure 13 is a block diagram of a computer system used in performing a method of a preferred embodiment of the present invention, forming part of an apparatus of a preferred embodiment of the present invention, storing a data structure of a preferred embodiment of the present invention, and which may use an article of manufacture comprising a computer-readable storage medium having a computer program embodied in said medium which may cause the computer system to practice a preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0026] An embodiment of the invention is now described with reference to the figures where like reference numbers indicate identical or functionally similar elements. Also in the figures, the left most digit of each reference number corresponds to the figure in which the reference number is first used. While specific configurations and arrangements are discussed, it should be understood that this is done for illustrative purposes only. A person skilled in the relevant art will recognize that other configurations and arrangements can be used without departing from the spirit and scope of the invention. It will be apparent to a person skilled in the relevant art that this invention can also be employed in a variety of other devices and applications.

[0027] Fig. 1 illustrates an editor screen or window 110 displaying a COBOL source code file in which a blank line 120 has been inserted by the user. The user may activate the code assist function by pressing a key or key combination, such as CONTROL-SPACE, which causes the code assist function to display a window 130 containing a list 140 of proposals or proposed candidates to insert at the current cursor position 120. The user may select one of the proposals from the list by clicking a mouse cursor on the proposal to be selected, and responsive to the user's selection of the selected proposal, the selected proposal is inserted at the current cursor position. The user may also scroll the list up and down to find the desired proposal. Alternatively, the user may use keystrokes, such as up arrow, down arrow, tab, return, or enter keys, to scroll, navigate, and select within the list 140.

[0028] If the user desires to insert a MOVE statement at the current cursor position 120, then the user may scroll down the list 140 until a MOVE keyword proposal is displayed. The user may then select the MOVE keyword proposal to be inserted which results in the window 210 of Fig. 2 in which the MOVE keyword 220 is inserted in the partial program statement 230, and in which the current cursor position 240 is moved after the inserted keyword. Responsive to the partial program statement 230 now comprising the MOVE keyword 220, the code assist function suggests further proposal candidates 250 for insertion at the now current cursor position 240. Based upon the syntax of a MOVE program statement, the code assist function suggests proposal candidates comprising the keywords CORRESPONDING and CORR which may follow the MOVE keyword, and comprising identifiers or variables declared within the program which may follow the MOVE keyword, but

excluding those identifiers which cannot be specified in a MOVE statement. For example, in some COBOL dialects, data items described with the following types of usage cannot be specified in a MOVE statement: INDEX, POINTER, FUNCTION-POINTER, PROCEDURE-POINTER, and OBJECT REFERENCE.

[0029] If the user selects the CORR keyword proposal 260 for the next insertion at the current cursor position 240, the window 310 of Fig. 3 results in which the CORR keyword 330 has been inserted at the end of the partial program statement 320 and in which the current cursor position 340 is moved after the inserted keyword 330. Responsive to the partial program statement 320 now comprising the MOVE and CORR keywords, the code assist function suggests further proposal candidates 350 for insertion at the now current cursor position 340. Based upon the syntax of the MOVE program statement, the code assist function suggests proposal candidates comprising identifiers or variables declared within the program which may follow the MOVE statement CORR keyword.

[0030] The user may now select one of the literal or variable proposals from 350 such as the In-Name proposal 360 for the next insertion at the current cursor position 340. The window 410 of Fig. 4 results in which the In-Name literal and TO keyword 430 have been inserted at the end of the partial program statement 420 and in which the current cursor position 440 is moved after the inserted literal and keyword 430. Responsive to the partial program statement 420 now comprising the MOVE and CORR keywords followed by the literal In-Name and the TO keyword, the code assist function suggests further proposal candidates 450 for insertion at the now current cursor position 440. Based upon the syntax of the MOVE program statement, the code assist function suggests proposal candidates comprising identifiers or variables declared within the program which may follow the MOVE statement TO keyword.

[0031] The literal or variable proposal Out-Name 460 from the window 450 may be selected by the user for the next insertion at the current cursor position 440. The window 510 of Fig. 5 results in which the Out-Name literal has been inserted at the end of the program statement 520. This insertion results in a complete program statement 520, and responsive to this complete program statement 520 comprising a complete MOVE program statement, the code assist function does not suggest any

1 further proposal candidates 350 for this complete program statement 520.

2
3 [0032] Referring now to **Figures 6** and **7**, graphical user interfaces which may be used to configure
4 the operation of the code assist function of the preferred embodiment are illustrated. Referring first
5 to **Fig. 6**, window **605** provides a graphical user interface which enables the user to specify user-
6 selectable preferences as to the operation of the code assist function of the preferred embodiment.
7 The user may select checklist item **610** to cause the code assist function to display a longer list of
8 candidates responsive to the parsing of a partial program instruction statement, or alternatively, the
9 user may select checklist item **615** to cause the code assist function to display a shorter list of
10 candidates responsive to the parsing of the partial program instruction statement. For example, the
11 longer list of candidates may comprise all candidates suggested by the code assist function; whereas,
12 the shorter list may comprise categories of candidates such as keywords, identifiers, or literals from
13 which the user may select to display the candidates in the selected category.

14
15 [0033] As a default behavior of the code assist function, the user may specify a preference as to
16 longer representations displaying full keywords or shorter representations displaying abbreviated
17 keywords in proposal candidates suggested by the code assist function. The user may select checklist
18 item **620** to cause a display of a longer representation of a program instruction keyword candidate
19 responsive to the parsing of a partial program instruction statement, or the user may select checklist
20 item **625** to cause a display of a shorter representation of a program instruction keyword candidate
21 responsive to the parsing of the partial program instruction statement. For example, if the user has
22 selected checklist item **620** indicating a preference for longer full keyword representations, then the
23 code assist function will display in suggested proposal candidates full keywords such as
24 "CORRESPONDING", "IDENTIFICATION", "JUSTIFIED", "PICTURE", "SYNCHRONIZED",
25 and "THROUGH". If the user has selected checklist item **625** indicating a preference for shorter
26 abbreviated keyword representations, then the code assist function will display in suggested proposal
27 candidates shorter abbreviated keywords such as "CORR", "ID", "JUST", "PIC", "SYNC", and
28 "THRU".

29
30 [0034] The user may also specify a preference as to the case of the suggest proposal candidates.
31 The user may select checklist item **630** to cause proposal candidates to be displayed in a lower-case

representation (i.e., "move"), checklist item **635** to cause proposal candidates to be displayed in an upper-case representation (i.e., "MOVE"), or checklist item **640** to cause proposal candidates to be displayed in a mixed-case or leading upper-case representation (i.e., "Move").

[0035] As a further default behavior of the code assist function, the user may specify a preference as to displaying a full syntax representation or a partial syntax representation. The user may select checklist item **645** to cause a display of a full syntax representation of a program instruction verb candidate responsive to the parsing of a partial program instruction statement, or the user may select checklist item **650** to cause a display of a partial syntax representation of a program instruction verb candidate responsive to the parsing of a partial program instruction statement. For example, if the user has selected checklist item **645** indicating a preference for a full syntax representation, then the code assist function will display a MOVE instruction candidate in the full syntax: "MOVE CORRESPONDING IDENTIFIER-1 TO IDENTIFIER-2". If the user has selected checklist item **650** indicating a preference for a partial syntax representation, then the code assist function may display a MOVE instruction candidate in a partial syntax: "MOVE IDENTIFIER-1 TO IDENTIFIER-2".

[0036] Although the user may specify user-selected preferences applicable to all candidates proposed by the code assist function, the user may also override these general preferences with verb-specific preferences by selecting checklist item **655** which causes a display of a list of verbs from which the user may select one verb to specify verb-specific preferences. If the user selects one of the verbs, such as "MOVE", to specify verb-specific preferences, then a window **700** of **Fig. 7** is displayed. Even though the user may have specified shorter abbreviated keywords as the default behavior of the code assist function, the user may specify a verb-specific preference of full keywords for the selected verb which overrides the general default behavior. For example, if the user has selected checklist item **705** indicating a preference for longer full keyword representations for the MOVE instruction, then the code assist function will display in suggested proposal candidates full keywords such as "MOVE CORRESPONDING" as opposed to the general preference of shorter abbreviated keywords such as "ADD CORR" or "SUBTRACT CORR". Similarly, checklist item **710** allows the user to override a general preference for longer full keywords with a verb-specific preference of shorter abbreviated keywords.

[0037] In a similar fashion, the user may use upper-case checklist item **715**, lower-case checklist item **720**, and mixed-case checklist item **725** to specify a verb-specific preference for the selected verb which overrides the general default behavior specified in window **605**.

[0038] The Statement Syntax section **730** of the verb-specific preferences window **700** allows the user to select one preferred syntax from a plurality of valid syntax representations. For example, for the MOVE instruction, Statement Syntax section **730** allows the user to select from a full keyword full syntax representation **735** comprising "MOVE CORRESPONDING IDENTIFIER1 TO IDENTIFIER2"; an abbreviated full syntax representation **740** comprising "MOVE CORR IDENTIFIER1 TO IDENTIFIER2", a partial syntax **750** comprising "MOVE IDENTIFIER1 TO IDENTIFIER2", or an alternative partial syntax **755** "MOVE LITERAL1 TO IDENTIFIER2". The preferred syntax selected by the user will be used by the code assist function when it suggests proposal candidates for that particular verb.

[0039] Alternatively, to select the syntax preference for the instruction, the user may click on the checklist item Selectable Statement Syntax **760** which allows the user to click on portions of the syntax diagram to specify the syntax preference. For example, the user may click on "MOVE" **765**, "CORRESPONDING" **770**, "IDENTIFIER1" **780**, "TO" **790**, and "IDENTIFIER2" **795** to identify and select the following full keyword full syntax representation of the MOVE instruction: "MOVE CORRESPONDING IDENTIFIER1 TO IDENTIFIER2". In lieu of selecting "CORRESPONDING" **770**, the user may select "CORR" **775** which results in the user identifying and selecting the following abbreviated keyword full syntax representation: "MOVE CORR IDENTIFIER1 TO IDENTIFIER2". If the user clicks on "MOVE" **765**, "IDENTIFIER1" **780**, "TO" **790**, and "IDENTIFIER2" **795**, then the partial syntax "MOVE IDENTIFIER1 TO IDENTIFIER2" is identified and selected as the syntax representation of the MOVE instruction. Alternatively, the user may click on "MOVE" **765**, "LITERAL1" **785**, "TO" **790**, and "IDENTIFIER2" **795** to identify and select the following alternative partial syntax representation of the MOVE instruction: "MOVE CORRESPONDING LITERAL1 TO IDENTIFIER2".

[0040] In lieu of these graphical user interface techniques, the user may select the checklist item

1 Edit Syntax Statement File **797** to directly edit the syntax statement rules contained in the syntax
2 statement file used by the code assist function parser.
3

4 **[0041]** Referring now to **Figure 8**, a block diagram of the preferred embodiment of the present
5 invention is illustrated. A programmer may open a program file **810** with editor **820** to edit program
6 source code contained in the program file **810**. If the programmer requests code assist or content
7 assist, it is provided by Code Assist Engine **830** which uses a Syntax Library appropriate for the
8 programming language in which the program of program file **810** is written. If program file **810** is
9 written in COBOL, then the Code Assist Engine **830** uses a COBOL Syntax Library **840** to provide
10 code assist. Alternatively, if the program file **810** is written in another programming language, such
11 as PL/I, C++, or Java for example, then the Code Assist Engine **830** uses either a PL/I Syntax Library
12 **850**, C++ Syntax Library **860**, or Java Syntax Library **870** to provide code assist. These
13 programming languages are merely exemplary examples as a Syntax Library may be written to
14 support any programming language. The Code Assist Engine **830** may determine which Syntax
15 Library is appropriate to use with program file **810** by analyzing either attributes or content of
16 program file **810**. For example, if a file attribute such as a file name extension is "cbl" indicating
17 that program file **810** is a COBOL program file, then the Code Assist Engine **830** uses COBOL
18 Syntax Library **840**. Alternatively, Code Assist Engine **830** may analyze the content of program file
19 **810** to determine that it contains COBOL program code and that COBOL Syntax Library **840** should
20 be used. In still other embodiments, the Syntax Library used by the Code Assist Engine **830** may be
21 based upon a user-specified preference, a user-specified selection, or a history file.
22

23 **[0042]** Referring now to **Figure 9**, a class diagram of the preferred embodiment of the present
24 invention is illustrated. The classes comprise a CompletionProcessor class **902**, Editor class **910**,
25 VariablesParser class **908**, UserStatement class **906**, SyntaxLibrary class **904**, CursorEngines class
26 **920**, Normal CursorEngine class **924**, and Recursive CursorEngine class **926**.
27

28 **[0043]** The CompletionProcessor class **902** manages the overall operation of the code assist
29 function, and comprises methods getCurrentText() **914**, getImages() **942**,
30 CompleteCompletionProposals() **952**, and completionProposals() **912**. The method getCurrentText()

1 **914** calls the editor **910** for the `elementText()` **916** to get the partial statement to be parsed to provide
2 code assist. The methods `CompleteCompletionProposals()` **952**, `completionProposals()` **912** and
3 `getImages()` **942** match a type from each proposal of the combined proposal vector to an image and
4 return these images to the `CompletionProcessor` **902**.

5
6 **[0044]** The `Editor` class **910** provides editing functions for the program file being edited, and
7 comprises `elementText()` **916** which provides the partial statement to `getCurrentText()` **914**.

8
9 **[0045]** The `VariablesParser` class **908** parses the program to identify variables and functional
10 constants, and comprises methods `getVariables()` **938**, `getDivision()` **954**, and
11 `getFigurativeConstants()` **940**. The method `getVariables()` **938** parses the program to identify
12 variables. The method `getDivision()` **954** gets Syntax Statements from `SyntaxLibrary` **904** to parse a
13 current division of the program file. The method `getFigurativeConstants()` **940** parses the program to
14 identify and get functional constants.

15
16 **[0046]** The `UserStatement` class **906** parses the partial statement based upon Syntax Statements
17 obtained from the Syntax Library **904**, and comprises methods `parseUserStatment()` **918**, and
18 `getStatement()` **948**. The method `parseUserStatment()` **918** parses the partial statement, and the
19 method `getStatement()` **948** returns the partial user statement entered by user in the editor for which
20 the user needs assistance.

21
22 **[0047]** The `SyntaxLibrary` class **904** stores an array of Syntax Statements describing the syntax of a
23 particular programming language, and comprises methods `getVerbs()` **956**, `getKeyWords()` **958**,
24 `isCommand()` **960**, `isKeyWord()` **962**, `getSyntaxStatmnts()` **964**, `getVariables()` **966**, and
25 `findSyntaxStatement()` **968**. The method `getVerbs()` **956** returns the commands supported by the
26 programming language for which the `SyntaxLibrary` stores the programming language syntax. A
27 command is normally the first keyword of a programming language statement. The method
28 `getKeyWords()` **958** returns the keywords, excluding command keywords, supported by the
29 programming language for which the `SyntaxLibrary` stores the programming language syntax. The
30 method `isCommand()` **960** tests whether a token is a command. The method `isKeyWord()` **962** tests

whether a token is a keyword. The method `getSyntaxStatmnts()` 964 gets the syntax statements as defined in a `SyntaxLibrary` for a particular programming language. The method `getVariables()` 966 gets the variables defined in the source program as detected by `VariablesParser`. The method `findSyntaxStatement()` 968 finds syntax statements in the `SyntaxLibrary` which match a given command.

[0048] Within the `SyntaxLibrary` class 904, language syntax diagrams are converted into syntax statement strings and stored in an array of strings forming a Syntax Statement Library. The first keyword in each syntax statement is the command or verb, and is distinguished from other keywords. When an incomplete programming language statement is presented to the Code Assist Engine 830, it matches the statement command or verb to the command keywords in the syntax statements producing a result comprising those matching syntax statements to be considered for subsequent processing which generates proposals.

[0049] Within syntax statements, special characters are used to delimit the syntax statements as follows:

<u>Character</u>	<u>Significance</u>
&n, &rn	“&n” and “&rn” are recursion labels. “&n” labels a start of a recursion within a syntax statement wherein n is a number from 0 to 9. An “&n” is paired with an “&rn” which indicates the end of a recursion. The second “&rn” causes a branch back or recursion to the first “&n”.
[]	Brackets indicate Or phrases in which a syntax statement requires either the first item located before the vertical bar within the brackets or the second item located after the vertical bar within the brackets.
{ }	“{” and “}” indicate phrase boundaries wherein once started a phrase must be completed, as opposed to Or phrases which do not have to be completed.
\$	“\$” indicates a conditional which may be applied to keywords (i.e., \$TO), Or phrases (i.e., \$[]), and phrases (i.e., \${ }).
&a	“&a” are symbol labels wherein “a” may be either “i”, “s”, “b”, “l”, “p”, etc. representing identifiers, statements, both, literal, procedure names, etc.

[0050] As stated above, a Syntax Statement Library is an array of syntax statement strings using the above notation. Given a syntax diagram for each format of each statement, the syntax statements may be written by matching the syntax diagram to the syntax statement notation, including recursion phrases. Different Syntax Statement Libraries may represent different programming languages without modifying the Code Assist Engine. Furthermore, different Syntax Statement Libraries may be used to represent the same programming language, such as having a different Syntax Statement Library for each COBOL division, like IDENTIFICATION, PROCEDURE, etc.

[0051] For example, the syntax of a COBOL ALTER statement may be represented by and stored in the Syntax Statement Library by the syntax statement:

`"ALTER &l &p TO ${PROCEED TO} &p &r1"`

Within this ALTER syntax statement, "ALTER", "TO" and "PROCEED" are keywords. "ALTER" as the first keyword in the syntax statement is considered to be the command or verb. Commands are determined by getting the first unique keyword in each syntax statement. "&l" and "&r1" are a recursive pair indicating the recursion "&l &p TO \${PROCEED TO} &p &r1". "{" and "}" mark a phrase "PROCEED TO" that once started must be completed. The "\$" marks the phrase "\${PROCEED TO}" as conditional or optional. "&p" represents a procedure symbol. Note that symbols from the syntax statement match identifiers or variables from the user statement and not keywords; whereas, keywords in the syntax statement match keywords in the user statement.

[0052] The processing of the syntax statements of the Syntax Statement Library occurs in two primary stages: moving the cursor, and creating proposals. The first stage of moving the cursor starts with a character string returned from `getCurrentText()`. This character string is the partial user statement. The partial user statement is parsed into tokens which are compared one by one against tokens in one or more syntax statements, such as the above mentioned COBOL syntax statement representing the COBOL ALTER command. Tokens are divided into keywords and variables. As long as matching between the user statement tokens and the syntax statement tokens occurs, the cursor is moved to the start of the next token. The cursor moving stage performs the token matching according to the keywords, phrases, and symbols specified in a syntax statement. When all of the tokens from the partial user statement are processed, the cursor moving stage is complete. If necessary, a same portion of a syntax statement (e.g., between "&l" and "&r1") is parsed again to

1 continue matching if a recursion is matched.

2
3 **[0053]** The second stage of creating proposals starts with a cursor index left by the first stage of
4 moving the cursor, wherein this cursor index indicates a position of the last matching tokens. The
5 second stage then moves forward from this cursor index position to generate one or more proposals.
6 For example, if the first cursor moving stage had matched the partial user statement against the
7 following ALTER syntax statement through the conditional "\$":

8 "ALTER &l &p TO \${PROCEED TO} &p &r1"

9 then the second stage of creating proposals starts with a cursor index pointing to the conditional "\$"
10 in the ALTER syntax statement as the first stage has already matched the tokens "ALTER &l &p
11 TO" between the syntax statement and the partial user statement. The second stage of creating
12 proposals will then generate "PROCEED TO" as a proposal. Since "PROCEED TO" is an optional
13 conditional, the second stage will also generate a proposal without "PROCEED TO" which would be
14 the next token comprising a procedure name.

15
16 **[0054]** If the cursor from the first stage is indexing the end of a recursion phrase, such as the "&r1"
17 in the above ALTER syntax statement, then the second stage would generate another proposal
18 comprising a second "&p TO &p", i.e., "procedure-name1 TO procedure-name2". If the cursor from
19 the first stage is indexing the start of an Or phrase, all of the alternative values within the Or phrase
20 would be generated as proposals.

21
22 **[0055]** The CursorEngines class 920 creates and controls a CursorEngine for each Syntax
23 Statement, and comprises methods createEngines() 922, generateProposals() 950, and
24 executeCursorEngines() 928. The method createEngines() 922 inspects a Syntax Statement and
25 creates an instance of a normal CursorEngine, and if it detects a recursion loop in the Syntax
26 Statement, then it also creates one instance of a recursive CursorEngine for each recursion loop
27 detected in the statement. The method generateProposals() 950 requests that each Normal
28 CursorEngine() 924 and each recursive CursorEngine() 926 created by its CursorEngines 920 to
29 create proposals based upon their prior parsing of the partial statement. The method
30 executeCursorEngines() 928 requests that each Normal CursorEngine() 924 and each recursive
31 CursorEngine() 926 created by its CursorEngines 920 begin cursor movement and parsing of the

partial statement.

[0056] The Normal CursorEngine class 924 parses a single Syntax Statement, and comprises methods moveSyntaxCursor() 930, parseSyntaxStatement() 944, and createProposal() 934. The methods moveSyntaxCursor() 930 and parseSyntaxStatement() 944 request that a normal CursorEngine parses its Syntax Statement as driven by the parsing of the partial statement. The method createProposal() 934 requests that a Normal CursorEngine() 924 create proposals based upon its prior parsing of the partial statement.

[0057] The Recursive CursorEngine class 926 parses a single recursion within a single Syntax Statement, and comprises methods moveSyntaxCursor() 932, parseSyntaxStatement() 946, and createProposal() 936. The methods moveSyntaxCursor() 932 and parseSyntaxStatement() 946 request that a Recursive CursorEngine parses its Syntax Statement as driven by the parsing of the partial statement. The method createProposal() 936 requests that a Recursive CursorEngine() 924 create proposals based upon its prior parsing of the partial statement.

[0058] Referring now to Figure 10 through Figure 12, the flowcharts 1000, 1100, and 1200 illustrate the operations preferred in carrying out the preferred embodiment of the present invention. In the flowcharts, the graphical conventions of a diamond for a test or decision and a rectangle for a process or function are used. These conventions are well understood by those skilled in the art, and the flowcharts are sufficient to enable one of ordinary skill to write code in any suitable computer programming language.

[0059] Referring first to Figure 10, after the start 1010 of the process 1000, process block 1020 creates an instance of a CompletionProcessor 902 registered for an appropriate programming language (i.e., cbl file extensions for COBOL), an instance of UserStatement 906, an instance of a VariablesParser 908, and an instance of a SyntaxLibrary 904 for each Division within the program file being edited by editor 910. Process block 1030 monitors for a user requesting the code assist function through the use of a key combination such as Control-Space after entering a partial COBOL statement. Alternatively, the user may activate the code assist function through other input devices and user interfaces well known to those skilled in the art. Responsive to the user's activation of the

code assist function, process block 1040 of the CompletionProcessor 902 calls CompletionProcessor#completionProposals() 912. Process block 1050 of the CompletionProcessor 902 calls getCurrentText() 914 which calls elementText() 916 of the editor 910 to get the partial statement upon which the code assist function was activated. The instance of UserStatement#parseStatment() 918 is called by process block 1060 of CompletionProcessor 902 to begin the proposal generation. UserStatement#parseStatment() 918 parses the partial statement provided by the editor 910 and uses a command (or verb) contained in the partial statement to locate Syntax Statement(s) via getStatement 948, locating one Syntax Statement for each format variation in the appropriate SyntaxLibrary 904 for the current COBOL Division. Process block 1070 creates one instance of CursorEngines 920 for each Syntax Statement format variation. Control then passes to process block 1120 on Figure 11, illustrated by flowchart connectors A, 1080 on Figure 10 and 1110 on Figure 11.

[0060] Referring now to Figure 11, after control passes to process block 1120, process block 1120 of createEngines() 922 inspects its Syntax Statement and creates one normal CursorEngine 924 and one recursive CursorEngine 926 for each recursion loop detected in the statement, if any. Process block 1130 of CursorEngines 920 invokes executeCursorEngines 928 to begin a cursor movement phase. During this cursor movement phase, process block 1140 of the normal CursorEngine 924 asks moveSyntaxCursor() 930 to parse its syntax statement via parseSyntaxStatement() 944 as driven by a parsing of the user-entered partial statement. If a recursive Syntax Statement is detected, then process block 1150 of the normal CursorEngine 924 calls an appropriate recursive CursorEngine 926 which asks moveSyntaxCursor() 932 to parse its recursive Syntax Statement via parseSyntaxStatement() 946 as driven by a parsing of the user-entered partial statement. Cursor movement within the user-entered partial statement continues until a recursive CursorEngine() 926 mis-matches tokens from the user-entered partial statement, or until the recursive CursorEngine() 926 reaches a match between its Syntax Statement and the partial user statement, at which point the recursive CursorEngine 926 returns to the normal CursorEngine 924. The normal CursorEngine 924 continues to move its cursor until a mis-match occurs, until more recursion syntax is reached, or until the end of the user-entered partial statement is reached. Control then passes to process block 1220 on Figure 12, illustrated by flowchart connectors B, 1160 on Figure 11 and 1210 on Figure 12.

1 [0061] Referring next to **Figure 12**, after control passes to process block 1220, process block 1220
2 begins the proposal generation phase in which generateProposals() 950 of CursorEngines() 920 asks
3 Normal CursorEngine() 924 and recursive CursorEngine() 926 to create proposals based upon their
4 prior parsing via createProposal() (934 and 936). To create these proposals, each CursorEngine (924
5 or 926), starting from the current cursor location, moves the cursor forward generating zero or more
6 proposals. Keywords from the Syntax Statement may added to a proposals vector as proposals. If
7 the current cursor position within the user-entered partial statement is setting on an identifier, then
8 corresponding variables and functional constants are obtained from VariablesParser#getVariables()
9 938 and VariablesParser#getFigurativeConstants() 940. These corresponding variables and
10 functional constants may also be added to the proposals vector. Thereafter, process block 1230
11 concatenates the proposals (strings and types) vectors from each CursorEngine (924 or 926) in each
12 instance of CursorEngines (924 or 926) across an array of format variation(s) to create a single
13 combined proposal vector which is returned to CompletionProcessor 902. Process block 1240 of
14 CompletionProcessor 902 causes completionProposals() 912 to match a type from each proposal of
15 the combined proposal vector to an image via getImages() 942 and to return these images to the
16 CompletionProcessor 902 which displays a pop-up window (130, 250, 350, or 450) containing the
17 proposal images from which the user can select a proposed Keyword, identifier or constant to
18 continue the entry of the partial statement. After all processing is completed, the process ends at
19 process block 1250.

20
21 [0062] With reference now to the figures, and in particular with reference to **Figure 13**, there is
22 depicted a pictorial representation of a computer system 1300 which may be utilized to implement a
23 method, system, article of manufacture, data structure, and computer program product of preferred
24 embodiments of the present invention. The block diagram of **Figure 13** illustrates a computer system
25 1300 used in performing the method of the present invention, forming part of the apparatus of the
26 present invention, and which may use the article of manufacture comprising a computer-readable
27 storage medium having a computer program embodied in said medium which may cause the
28 computer system to practice the present invention. The computer system 1300 includes a processor
29 1302, which includes a central processing unit (CPU) 1304, and a memory 1306. Additional
30 memory, in the form of a hard disk file storage 1308 and a computer-readable storage device 1310, is

1 connected to the processor 1302. Computer-readable storage device 1310 receives a computer-
2 readable storage medium 1312 having a computer program embodied in said medium which may
3 cause the computer system to implement the present invention in the computer system 1300. The
4 computer system 1300 includes user interface hardware, including a mouse 1314 and a keyboard
5 1316 for allowing user input to the processor 1302 and a display 1318 for presenting visual data to
6 the user. The computer system may also include a printer 1320.

7
8 **[0063]** Using the foregoing specification, the invention may be implemented using standard
9 programming and/or engineering techniques using computer programming software, firmware,
10 hardware or any combination or sub-combination thereof. Any such resulting program(s), having
11 computer readable program code means, may be embodied within one or more computer usable
12 media such as fixed (hard) drives, disk, diskettes, optical disks, magnetic tape, semiconductor
13 memories such as Read-Only Memory (ROM), Programmable Read-Only Memory (PROM), etc., or
14 any memory or transmitting device, thereby making a computer program product, i.e., an article of
15 manufacture, according to the invention. The article of manufacture containing the computer
16 programming code may be made and/or used by executing the code directly or indirectly from one
17 medium, by copying the code from one medium to another medium, or by transmitting the code over
18 a network. An apparatus for making, using, or selling the invention may be one or more processing
19 systems including, but not limited to, central processing unit (CPU), memory, storage devices,
20 communication links, communication devices, servers, input/output (I/O) devices, or any sub-
21 components or individual parts of one or more processing systems, including software, firmware,
22 hardware or any combination or sub-combination thereof, which embody the invention as set forth in
23 the claims. User input may be received from the keyboard, mouse, pen, voice, touch screen, or any
24 other means by which a human can input data to a computer, including through other programs such
25 as application programs, databases, data sets, or files.

26
27 **[0064]** One skilled in the art of computer science will easily be able to combine the software
28 created as described with appropriate general purpose or special purpose computer hardware to
29 create a computer system and/or computer sub-components embodying the invention and to create a
30 computer system and/or computer sub-components for carrying out the method of the invention.
31 Although the present invention has been particularly shown and described with reference to a

1 preferred embodiment, it should be apparent that modifications and adaptations to that embodiment
2 may occur to one skilled in the art without departing from the spirit or scope of the present invention
3 as set forth in the following claims.